Journal of Advances and Scholarly Researches in Allied Education
Vol. 17, Issue No. 2, October-2020, ISSN 2230-7540

Design and Development of Sustainable Lean Manufacturing Using Interpretive Structural Model (ISM) Approach

Mr. Jaideep[1]* Dr. Rakesh Rajpal[2]

[1] Research Scholar, Department of Mechanical Engineering, Singhania University, Jhunjhunu, Rajasthan

[2] Research Supervisor, Department of Mechanical Engineering, Singhania University, Jhunjhunu, Rajasthan

Abstract – The survival of any organization depends upon its competitive edge. Even though Lean is one of the most powerful quality improvement methodologies, nearly two-thirds of the Lean implementations results in failures and less than one-fifth of those implemented have sustained results. One of the most significant tasks of top management is to identify, understand and deploy the significant Lean practices like quality circle, Kanban, Just-in-time purchasing, etc. The term 'parameters' is used to make groups of inter-related and internally consistent Lean practices. Eight significant Lean practice parameters have been identified based on literature reviewed and opinion of the experts. The order of execution of Lean practice parameters is very important. Lean practitioners must be able to understand the interrelationship between these practice parameters. The objective of this paper is to develop framework for sustainable Lean implementation using interpretive structural modelling approach. The main objectives of this paper are:

To identify and prioritize the Lean practices parameters

- ***To discover and analyse the interaction among identified Lean practices parameters using ISM and***
- ***To develop a framework for sustainable Lean implementation***

In this research, study factors are the Lean practices bundles for successful Lean implementation. Authors have identified twelve significant Lean practices parameters from literature review and opinion of the experts.

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INTRODUCTION

In many ways, Lean is an advanced version of just-in-time (JIT). For all practical purposes they share the same approach to change. Both are focused on the process adding value and eliminating waste in the process Both methods also origin in the Toyota production system (TPS) At the heart of the Toyota production system (TPS) is a production system that has become known as JIT. The TPS JIT theory (or Lean production theory as it is now called) relies on a pull-type production system, where only the parts that are needed are present (plus a minimal number of additional units for the approaching work in progress)

The success of the Japanese in the employment of JIT production has received a great deal of attention in the past two decades Severe competition, demand for cost-effective product, demand for qualitative on time-in full delivery at right place, marketing and economic issues, etc., forced many organizations to adopt JIT/Lean concepts in the last decades. Currently, in India about 150 companies in the automobile industry use Lean manufacturing, but it is yet to permeate other areas In India, companies like Maruti Udyog Limited (MUL), Eicher, Escorts, Telco, Tisco, TVS, etc., have adopted JIT-based systems and improved their product quality

Although there is evidence that some manufacturing companies in India have adopted Lean manufacturing practices and VSM as improvement approaches, several studies and authors argue that this application is either feeble or has not been fully successful. The traditional Lean paradigm results in nearly two-thirds of the implementations ending in failure while only 16.67 % of those implemented have sustained results—though for less than twelve months Indian

industry is still struggling to implement Lean principles and philosophies. The failure in managing Lean implementation process is often consolidated to poor mindset and inadequate understanding of the Lean concept itself .Benton and Shin mentioned that the major implementation problems centre on cultural, human, and geographical factors. In fact, there is a list of reasons why the Toyota manufacturing system does not work in western firms. The reasons include cultural differences, geographical dispersion of suppliers, and different management styles, etc.

Successful Lean system demands an integrated structure of supporting practices. Support of TPS practices is integral part of sustainable Lean implementation. The TPS is not a toolbox, where a company can pick out the instruments that appear to be useful, but represents an approach that has to apply all TPS principles as a system in order to be effective. Furthermore, it is important to note that success necessitates the integration of TPS practices and definitely not highly selective use of just one practice Hitherto, US manufacturers have been unable to replicate the success of JIT management practices used by their Japanese counterparts. White et al. believe the sequences of implementations have been ineffective and are the reasons for these results.

There are more than hundred Lean practices available and being practiced by industries. In this research, the critical Lean practices commonly cited by many researchers are only considered. Lean practices include quality circle, total quality management (TQM), total productive maintenance (TPM), kanban, single-minute exchange of die (SMED), etc. These Lean practices act as enablers for successful implementation of Lean system. The Lean practice parameters not only affect the successful implementation of Lean but also influence one another. Thus, it is very essential to understand the mutual relationship among the Lean practice parameters. Some practice parameters lay foundation for the other Lean practice parameters. Some are dependent, some are independents and some have interrelationship. The practice parameters which have high driving power and dependency need more attention. The sequential approach of implementation of these practice parameters is essential.

The understanding of the hierarchy of Lean practice parameters would be helpful for the top management implementing the Lean concepts. To motivate the industry towards Lean implementation, significant Lean practice parameters required to be identified, analysed and discussed. This can be a guide for taking appropriate action for successful implementation of Lean system. The effective and sustainable implementation of Lean assumes tremendous significance in this context.

Lot of research has been carried out in the field of modeling Lean system. Some researchers did empirical studies and presented conceptual or theoretical models. Various modelling tools and techniques based on the mathematics, statistics, operation research (OR), computer simulation, structural equation modelling, AHP, Petri nets, etc., were used. More details on existing Lean models are described in Section 3. But as far as authors' literature review on Lean and JIT is concern nobody used interpretive structural modelling (ISM) for JIT or Lean systems. The prime purpose of this paper is to offer a framework for sustainable Lean implementation in manufacturing industry. The authors attempt to expand the body of knowledge by considering the following two criteria.

- Developing the relationship between each of critical Lean practice parameters and
- Developing a framework for sustainable Lean implementation

The research is based on secondary data, which includes compilation of research articles, web articles, survey reports, thesis and books, etc., on automotive industry. The main aspect of the paper is the development of roadmap for sustainable Lean implementation using ISM methodology. The salient features of the research are:

- It represents the collective wisdom of Lean practitioners in the form of interpretive structural model.
- It offers phase-wise road map for sustainable Lean implementation based on ISM.

LITERATURE REVIEW

(Driouach, L., Zarbane, K., Beidouri, Z., 2019). The competitive industrial environment encourages these companies to redesign their manufacturing practices. Nowadays, Lean Manufacturing (LM) has been widely implemented in several industries and has show an efficient development towards more performant companies. However, to benefit from the LM, implementation process needs to be well-performed and certain Critical Success Factors have to be considered, such as commitment and support from management, training sessions, employee involvement and so on. The aim of the current review is to emphasize the recent progress of LM inside SME worldwide. The current review shows that most successful LM initiatives are those implemented in SME and big companies. However, Very Small Businesses (VSBs) are struggling in order to introduce Lean Manufacturing to their process. A new approach has been developed to establish

a new Lean implementation framework that could be adapted to the specific context of VSB

(Ankur Chauhan, Amol Singh & Sanjay Jharkharia, 2018) Increasing amount of wastes is posing great difficulties for all countries across the world. The problem of waste management is more severe in developing countries such as India where the rates of economic growth and urbanization are increasing at a fast pace. The governments in these countries are often constrained by limited technical and financial capabilities, which prevent them from effectively addressing these problems. There is a limited participation from the private players too in terms of setting up of waste recycling units. The present study aims at identifying various barriers that challenge the establishment of these units, specific to India.

(Manuela Ingaldi, Szymon T. Dziuba and Anna Cierniak-Emerych, 2018) Changes are inherent in activity of any enterprise. Several methods or concepts can be employed to introduce changes. One of the concepts which has become popular recently and improves enterprise's functioning is Lean Manufacturing. There are multiple techniques and tools which function within this method. Unfortunately, in the case of any changes, also in the case of implementation of Lean Manufacturing components, one can meet the resistance of employers and a number of technical and organizational problems. The aim of the paper is to collect and analyze information concerning the problems that occur during implementation of the Lean Manufacturing in Polish enterprises..

(Arvind Kumar Shrimali, Vimlesh Kumar Soni, and Shashank Singh Pawar, 2018) Lean practices are implemented in manufacturing companies and services to find hidden waste and attain continuous improvement. Various enterprises have experienced difficulties in the Lean implementation. Following the use of appropriate lean instruments and techniques, there are many other factors that affect success lean implementation process. Researchers have identified a huge number of barriers to the implementation of Lean. Understanding the barriers and the interactions between them can be crucial to the success of lean implementation. Interpretive Structural Modeling (ISM) is one of the established methodologies to bring forward the interrelationships among parameters of an issue or a problem. Purpose- The purpose of this paper is to create the hierarchy of the various barriers to Lean Implementation according to their importance using the approach of ISM to facilitate Small and Medium Enterprises (SMEs) across India. The study is specific to the Small and Medium Enterprises (SMEs) from India.

(Abdillah Arif Nasution, Ikhsan Siregar, Anizar, Tigor Hamonangan Nasution, Khalida Syahputri Indah Rizkya, 2018) This research was conducted in manufacturing industry, so this research is based on case study application. This research serves to reduce waste in the industry when making a product. This study categorizes value-added work and which work has no added value. And it is measurable and has value, so it can be evaluated in the future. Later this will be poured or depicted on a map called Value stream mapping. This is a tool from Lean Manufacturing. Lean manufacturing is useful for analyzing and reducing non value-added activities, value stream mapping analysis tools, 5L1H process mapping activities, and 5 why tools. From the results of this study obtained the efficiency of the process cycle and total estimation of the improvement of the lead time. This calculation can be an evaluation material for the company.

(Rajender Kumara, Vikas Kumar and Singh, 2017) Existing literature on lean principles reveals the impact of lean principles on the organizational performance. During the past few years, the Indian manufacturing context has been competing with the global competitors directly to sustain their presence. One of the big motivations behind this is the steps taken in favor of replacing the policies and regulations for the manufacturing context by the government of India. In present, the manufacturing context is still far away to get the sustainable market because of customer perception variation i.e. cost, delivery and quality related issues. To overcome the uncertainties based on the attributes i.e. quality, productivity, de-livery etc., almost all the manufacturing units use the basic of lean principle i.e. apply the 5'S. Whereas the heavy industries used the VSM approach especially the automotive product manufacturers. The work presented in this paper gives an insight on the application of lean principles in the manufacturing context and analyzes the impacts using ISM approach

(Marcos José Alves Pinto Junior, Juliana Veiga Mendes, 2017)A literature review was conducted to analyze the relationship between operational practices of Lean and reduction of environmental impact in organizational contexts. Verified theoretically, this relationship was observed in a company of the electronics industry, through an exploratory research which contemplated a mixed approach. The adopted research method consisted of a single case study, by providing greater depth and detail of the study. Utilized a research protocol, validated test pilot. The instruments for data collection were semi-structured interviews, direct observation and document analysis. The information was examined qualitatively considering the technique for content analysis. As a result of the study, it was found that there is evidence for the existence of relationship between the practices of Lean, for example, Kaizen, PDCA (plan, do, check, act), Ishikawa Diagram, Poka-Yoke, Standardized Work and Value Stream Mapping, with the reduction of environmental impacts of an organization. This reduction was observed after application of these practices that resulted in the

reduction of energy consumption, water and waste generation. The study presents in detail, the application of operational practices of Lean Manufacturing, with an effective view to reducing the environmental impact and cost reduction. The literature review, a detailed description of the application process and financial results are important information that contributes to the scientific studies that address traditional operating practices and the search for better environmental performance.

(Rajesh Attri, Nikhil Dev and Vivek Sharma, 2013) Interpretive structural modelling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. This approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue. ISM approach starts with an identification of variables, which are relevant to the problem or issue. Then a contextually relevant subordinate relation is chosen. Having decided the contextual relation, a structural self-interaction matrix (SSIM) is developed based on pair wise comparison of variables. After this, SSIM is converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is derived. In this paper, key concept of ISM approach is discussed in detail.

(Lathin, 2009) insist that quality improvements are only possible if companies implement comprehensive change management programs addressing "both the organizational and technological aspects of quality management".

(Imai, 2007) Eight distinct types of waste are recognized in the Lean manufacturing system cause effective implementation of Lean management results in the establishment of intra and inter organizational capability building routines and improve time – based competitiveness depends on the use of this Lean principles, structured processes and supporting tools. (Ford & Crowther, 2006)

The purpose of this paper is to provide a historical account of the significant role that Connecticut businesses and business leaders had in the spread of Lean management throughout the USA. The paper aims to describe what happens when managers do not understand and apply an important principle of Lean management.

Survey of published and unpublished records, as well as personal communications with key figures. Findings – Establishes the role and importance of Connecticut businesses and business leaders in the discovery and dissemination of Lean management in America since 1979, external to Toyota and its affiliated suppliers. Research limitations/implications – The accuracy of some past events necessarily relies on the recollection of key figures that were obtained by personal communications.

Describes how an important principle, "respect for people," was not understood by most management practitioners, thus hindering efforts to correctly practice Lean management and improve business performance. Originality/value – The paper provides a historical account of Lean management in America, focusing on activities that occurred in the State of Connecticut

(Taj & Berro, 2006) To increase productivity in an automotive assembly plant to satisfy customer demand and also develop best practices for productivity improvement for robotic welding operation lines. Design/methodology/approach – Principles of lean manufacturing and constrained management have been applied to increase the plant's output in order. Constrained management was used to identify bottlenecks in the plant that limits the throughput and lean manufacturing helped to identify waste (muda) in the constrained production areas. Analytical tools such as matrices are used for mapping sequence of robotics movements to identify interference and desired path for welding line. Findings – Results of applying constrained management and lean manufacturing in tandem have revealed the plant's overall bottlenecks and means of increasing the throughput. Research limitations/implications – The research findings are from an automotive assembly plant in a mass production industry, and the results may not be applicable to other types of industry. Practical implications – A very useful best practice for the productivity improvement that is easy to use by plants' management to help them identify and manage bottlenecks, and to eliminate waste from the production system. Originality/value – This paper offers practical and easy-to-use productivity improvement tools based on lean and constrained management principles to help manufacturing managers to make their operations more productive.

(Emiliani, 2006) The purpose of this paper is to provide a historical account of the significant role that Connecticut businesses and business leaders had in the spread of Lean management throughout the USA. The paper aims to describe what happens when managers do not understand and apply an important principle of Lean management. Survey of published and unpublished records, as well as personal communications with key figures. Establishes the role and importance of Connecticut businesses and business leaders in the discovery and dissemination of Lean management in America since 1979, external to Toyota and its affiliated suppliers. The accuracy of some past events necessarily relies on the recollection of key figures

that were obtained by personal communications. Describes how an important principle, "respect for people," was not understood by most management practitioners, thus hindering efforts to correctly practice Lean management and improve business performance. The paper provides a historical account of Lean management in America, focusing on activities that occurred in the State of Connecticut post-1979. Description and relevance of a key area of misunderstanding among practitioners of the Lean management system.

(Bhasin and Burcher, 2006) Lean Manufacturing is an efficient and fast growing approach in the world of competition. Lean Manufacturing is employed for the incessant removal wastes in the manufacturing to improve the efficiency and productivity. The main focus of the lean manufacturing is to satisfy customer demands for high quality and low cost. The technique not only identifies the reasons for waste but also helps in its removal through marked principles and guidelines. This paper focuses on discussing the concepts of lean manufacturing to improve the productivity, and quality and lower the cost of the product. Types of wastes are defined. The tools used to lower the waste are discussed.

(Henderson et al, 2004) The purpose of this paper is to provide a historical account for the role of management in implementation of lean thinking in a lean manufacturing environment. This paper initiated with literature which introduce the lean manufacturing as the combination of directions and a culture which managers through the guidelines in implementations can achieve the benefits. Implicitly, the two basic line of lean manufacturing, 'respect to the workforce' and 'waste elimination' is introduced and how these factors can cause an effective leadership during implementations. In continue, it is described that how every companies use the benefits of lean tools in their conception with lean implementations, and what factors the managers involve with culture and leaderships issues.

(Mejabi, 2003) This paper presents a planning system for lean manufacturing and is applicable to a variety of manual and automated manufacturing operations. By defining a standard set of lean manufacturing metrics, our research sets up a framework for performance measurement and benchmarking. A financial cost of waste measure is developed from data on current performance levels, and the planning framework develops a lean scorecard that establishes the gap between current performance and desired stretch performance targets, to facilitate planning for closure of the performance gap. For planning, users select one or more of 14 standard lean manufacturing strategies ranging from Kanban or pull systems, to manufacturing cells. Each strategy can be implemented at a basic or comprehensive level. In addition, projected performance improvements are used to estimate the performance improvements for each of the metrics. Finally, a lean manufacturing cash flow summary is developed to show cost of waste, cost of lean implementation, and lean savings over a five-year period. Together, these cash flows make it possible to compute a Return on Investment (ROI) evaluation of the lean manufacturing expenditures.

(Whilst Lathin and Mitchell, 2001) Global competition in business has forced most production sectors to realign their strategies to achieve competitive advantage. In flour producing companies in Kenya, the problem of broad production has been in place and as advanced technology takes its roots in Africa, there has been an increasing demand for quality output by the industry; which can be achieved by effective adoption of various production systems. The paper sought to assess the effects of lean production on organizational performance. The study was designed determine the elements of lean production, effect of lean production systems on product quality, strategies for waste reduction and the challenges of adopting lean production. The study adopted a descriptive research design.

(Sheridan, 2000) proposes that lean implementation takes: "three years to become competent in applying such tools as set-up reduction, standard work or cell building and five years to introduce gradually a firm belief in all the tools".

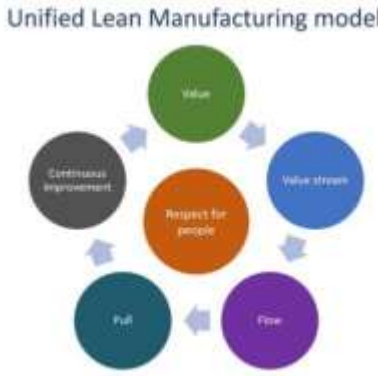
(George Koenigsaecker, 2000) Who has directed lean conversion initiatives in 18 manufacturing plants comments: "often people who attempt a lean conversion start with one of the tools, or a couple, and they push them through the organization.

During the 1950s, the emerging post war Japanese Industrialists began to challenge some of the precepts of this management approach and amongst the foremost of the pioneers were Toyota, Honda and a number of other volume producing organizations.

RESEARCH METHODOLOGY

One of the most important directions of research in contemporary times is the necessity, potentials and possibility of developing methodologies and applications tools and techniques aimed at improving machine tool manufacturing practices. This will focus primarily on cutting down wastes in operations as pioneered by Henry Ford and later practiced by the Toyota production system. The successful effort to reduce an initial assembly time of 728 minutes to 93-minutes output rate after five years of attempts by Henry Ford in his company in1913 is the outcome of a lean effort. However, the lean drive in manufacturing has been relatively passive for many decades. Lean is usually achieved with the use of tools, including mistake proving, value stream mapping, visual

management and pull-production, which are world-class tools and techniques successfully applied in other areas such as the automobile sector. This philosophy of improvement through waste reduction is referred to as lean approach. Unfortunately, despite the wide complexity of operations involved in the machine tool manufacturing industry, comprehensive experimental investigations on machine tool manufacturing using lean approaches are still not enough. The strong pursuit of such a goal to cut down wastes using lean philosophy would ensure sustainability and competitiveness of the machine tool manufacturing sector, which is considered as a foremost sector in terms of technological innovation, particularly in India. In the machine tool manufacturing industry, targeted wastes for reduction or elimination include defective processed parts, unnecessary transportation of worker and materials at the shop floor, excessive in-process inventories, waiting for instruction from the superior on the next action to take during operations processing, spare parts over-production and over processing of parts and components. These wastes must be reduced or eliminated for better competitiveness of the industry. Certainly, more research is necessary in the lean manufacturing area as exemplified by the economic crisis worldwide, which has resulted in turbulent environmental conditions for machine tool manufacturing practices. Competition among the machine tool manufacturing industrial players is also keen, thus requiring a more judicious utilization of manufacturing resources and on the cautious waste-avoidance practices. Lean manufacturing, a foremost waste-cutting philosophy is therefore a potential and promising concept for the machine tool manufacturing industry. Till date, very sparse reports exist on lean manufacturing applications and the study of lean practices within the growing Indian economy with respect to machine tools industry.



Applying the philosophy of lean requires a fundamental shift in the way one thinks about business processes. Lean philosophy is all about eliminating waste. Any action or process that does not add value in the eyes of the customer is waste and should be prevented or eliminated. For example: View the activities in the processes from the perspective of the customer. Which activities in the process add value for the customer? Think from the perspective of the part, product, or service as it goes through the process. Walk the path that a part travels. Look for ways to reduce the distance travelled and reduce the number of times the part is handled. View the process as end-to-end, not just as individual steps. Don't optimize individual areas while sub-optimizing the whole. Look for ways to standardize processes across products. When the operations are lean, each remaining activity adds value from the customer's perspective. Activities that do not add value represent wastes. Each type of waste adds cost and delay to the product or service but doesn't add value for the customer. To stay ahead in today's highly competitive global economy; waste in the enterprise must be identified and eliminated.

RESULT AND CONCLUSION

These identified variables have been listed in Table and a questionnaire based study had been carried out and respondents were asked to rank above variables on Likert scale of 1-5 (where 1 means "not important" and 5 means "most - important"). Fifty Six questionnaires were sent to respondents, out of them forty Eight questionnaires were received back and forty two questionnaires were considered for research work, whereas six questionnaires were discarded due to incompletion.

Sr. No.	Lean Manufacturing System implementation Variables	Researchers
1	Quality of human resources	Yu Lin &Hui Ho (2008); Åhlström (1998); Womack, Jones &Roos (1990).
2	Production Planning & Control	Hayes & Wheelwright (1984); Skinner (1974); Poppendieck (2002); Heizer& Render (2006); Womack et al. (1990).
3	Part standardization to reduce complexity and excessive processing	Kasul&Motwani (1997); Liker (2004).
4	Plant Layout & Ergonomics	Walder, Karlin&Kerk (2007).
5	Collaborative decision making	Kasul&Motwani (1997); Ahuja (1996).
6	Proper utilization of floor space	Heragu (1997).
7	Minimization of defects	LEI (2003).
8	Customer involvement	Panizzolo (1998).
9	Improved quality of raw material	Nakamura, Sakakibara& Schroeder (1998); Forza (1996); Shah & Ward (2003); Taj (2008).
10	Reduction in unnecessary inventory	Liker (2004).
11	Top management commitment	Hamel &Prahald (1989).
12	Optimization of transportation and material handling cost	LEI (2003); Karlsson&Åhlström (1996); Womack et al. (1990).

From the final reachability matrix, the structural model is generated known as diagraph. After removing the transitivity links and replacing the node numbers by statements, the ISM model is generated which has been shown in Figure No. 20. It has been observed from Figure that 'Top management commitment' has been very significant variable for lean manufacturing system implementation in the Indian arc welding electrode manufacturing industry as it comes at the base of the ISM hierarchy.' Plant Layout and ergonomics has been identified as the top level.

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Corresponding Author

Mr. Jaideep*

Research Scholar, Department of Mechanical Engineering, Singhania University, Jhunjhunu, Rajasthan

jaikadian@yahoo.co.in